Recovery of RGB Image from Its Halftoned Version based on DWT

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***Abstract*— Halftoning of image is a way of compressing both RGB and grayscale image where instead of continuous levels or tone of pixels, only two discrete levels of pixels are considered. Actually a halftone image resembles a binary image in context of bits of pixels but the size and shape of pixels are modified to make it better in visualization. In this paper, we used two dimensional filtering techniques and discrete wavelet transform (DWT) with thresholding to recover an RGB image from its halftoned version. We compared the original and recovered image based on six largest eigen values, the SNR in dB and cross-correlation co-efficient of Red, Green and Blue components. The algorithm we used here shows 94% or above similarity between original and recovered image. This paper is actually the extended version of the previous paper of grayscale image.**

Keywords-* *Signal to noise ratio, 2D filtering, standard deviation, eigen value, cross-correlation coefficient.

I. INTRODUCTION

A halftone image is actually a binary image of different formats. In a gray scale binary image each pixel is represented by a binary bit 1 or 0 against white or black; provided size of each pixel is equal. A halftone image is also made up of dots but size is not equal like binary image. In a colored half-tone image the dots are variable in sizes, shapes, colors. The half-tone image takes the opportunity to represent dark areas with large dots while small dots are used to represent lighter areas. Halftoning is widely used in display devices like newspaper printers, laser printers, even some computer screens to reduce the size of image. The spectrum of an image mainly consists of low, medium and high frequency components. Human eye is highly sensitive to low frequency components and in halftone images the low frequency component is approximately same as the continuous tone image. The high-frequency component is not correlated with the low-frequency component of an image and does not convey vital information of an image as discussed in [1]. The human visual system approximately acts as a low-pass filter hence a half-tone image gives the illusion of continuous tone image from a distance. On the other hand, storage capacity and transmission time of an image is an important issue satisfied by such image. The two basic operations of halftoning are: dithering and error diffusion discussed in [1-3] and theirs inverse operation is found in [4]. Among several inverse algorithm methods: digital filtering method is shown in [5] and error diffusion method is analyzed in [6]. The quality of halftone image is analyzed in [7] using the concept of amplitude modulation (AM) and frequency modulation (FM).

In this paper we use error diffused halftone (error is diffused to surrounding pixels) under Floyd-Steinberg mask to produce halftoning dots of image. Actually halftone is a lossy compression like JPEG (Joint Photographic Expert Group), hence its recovery is also lossy but the proposed method provides a good impression. The computation complexity is less and the process time used here is also too small compared to the other existing models at the expense of quality of the image. Here we combined filtering and discrete wavelet transform with thresholding technique to recover the RGB image from its lossy halftone image. We use two parameters: cross-correlation co-efficient and six eigenvalues to measure the similarity of original and recovered image. The RED, GREEN and BLUE plates of RGB image is used as the matrices of real number like [8] for comparison. Finally recovered image is de-noised using Discrete Wavelet Transform (DWT) of [9]. Similar work was done by the third author of the paper in [10] only for gray scale image, but this paper gives the extension of [10] for RGB image which is actually three times more complex compared to it.

The rest of the paper is organized as: section II provides the algorithm of conversion of an RGB image into colored halftone image and its recovering techniques, section III deals with the results based on analysis of section II and section IV concludes entire analysis.

II. System Model

The algorithm to convert an RGB image into colored halftone image and way of recovery of lossy image is given below:

1) *Read the original RGB image.*
2) *Separate R, G, and B components of the image.*
3) *Convert each component of the image into halftone image using Floyd-Steignberg algorithm. Let us denote each halftone component as R_h, G_h and B_h.*
4) *Reconstruct the halftone RGB image combining R_h, G_h and B_h.*
5) *Display both the original and halftone image for comparison.*
6) *Smoothen each component of the halftone image making convolution with 2D filtering (motion, average, disk, Gaussian). Combine the filter matrix to form smooth RGB image.*
7) *Display the smooth image for comparison.*
8) *Apply DWT on the filtered image with hard threshold to remove noise grain of the filtered image.*

III. Results

We consider four test image (RGB images) shown in figure 1 to 4. Each figure composed of four components: original image, half-tone image, recovered image after convolution and de-noised image (applying DWT). First of all, we compare the original and recovered images in context of eigen values. The six largest eigen values (λ_i; i = 1, 2, 3, …, 6) of original and recovered image are evaluated for R, G and B components using MATLAB 16. For the combination of Gaussian filter and DWT, we made the comparison in tabular form shown in Table (I-IV). From all the tables, we can see that error is found less than 7% and at a glance, the recovered images resemble to the original images.

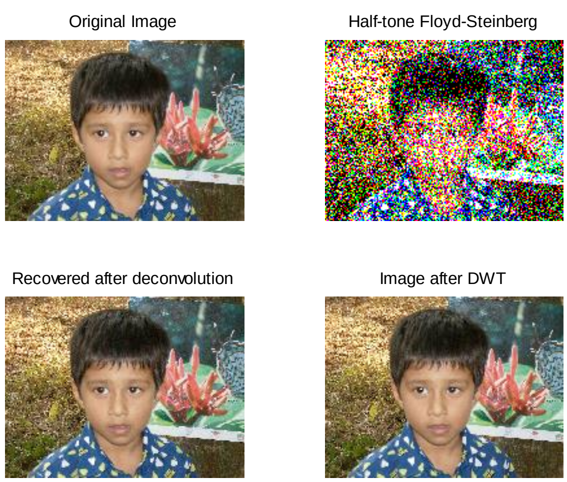

Figure 1. Siam as the test image

Figure 2. Statue of war '71 as the test image

Figure 3. Jahangirnagar University gate as the test image

Figure 4. Vegetables as the test image

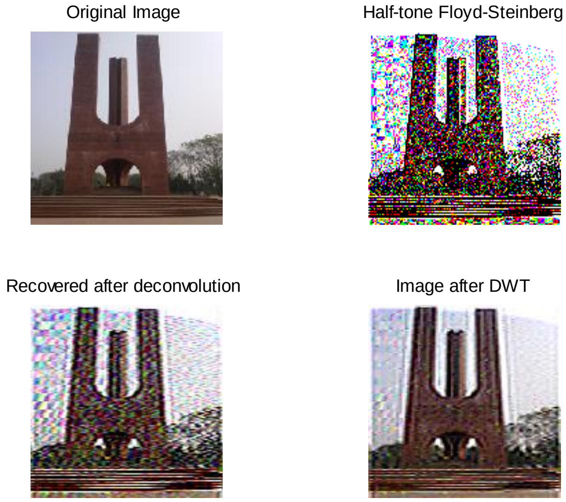

Figure 5. Motion Filter on the image of Victory Monument

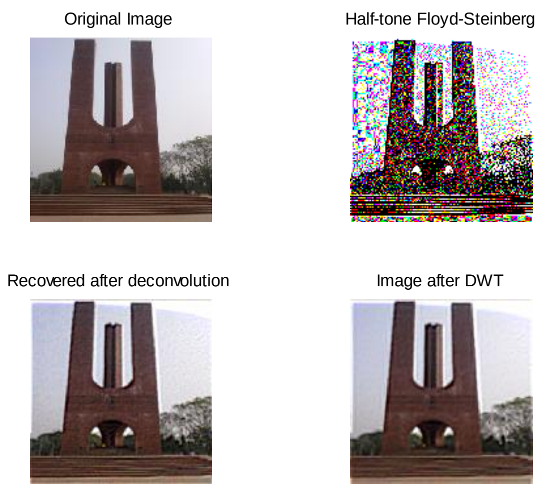

Figure 6. Gaussian Filter on the image of Victory Monument

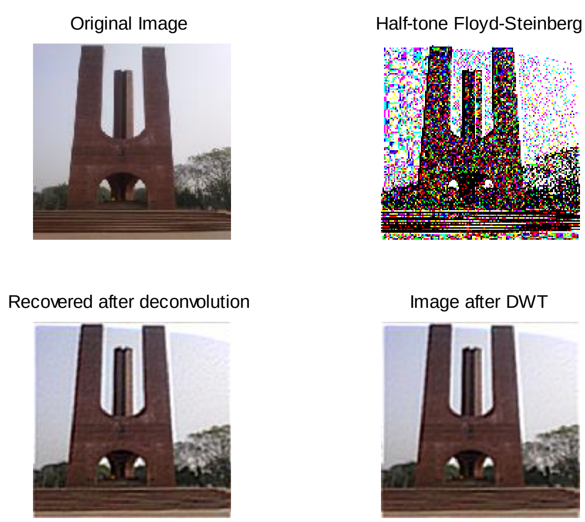

Figure 7. Disk Filter in Victory Monument Image

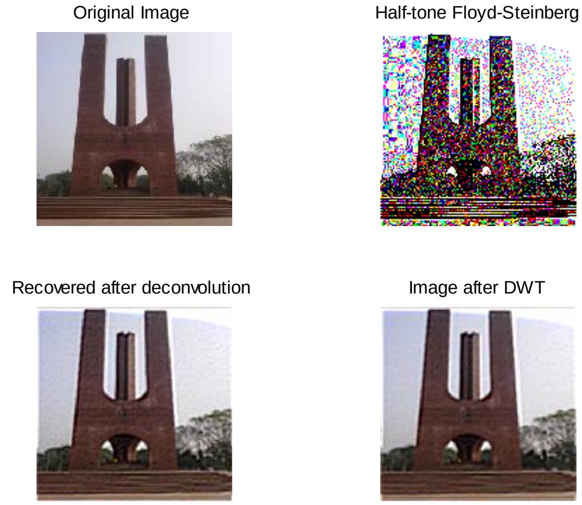

Figure 8. Average Filter in Victory Monument Image

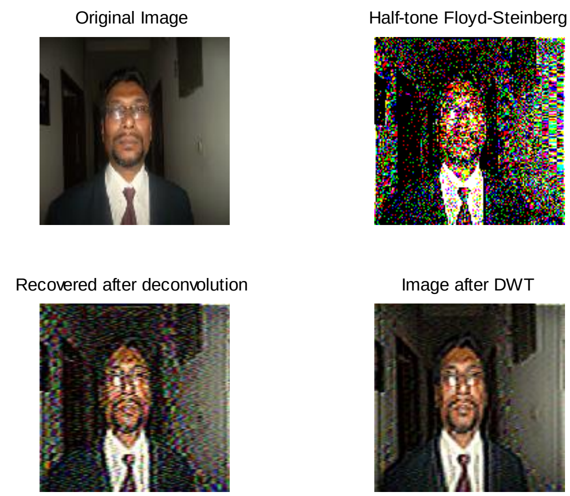

Figure 9. Motion Filter in Imdad Image

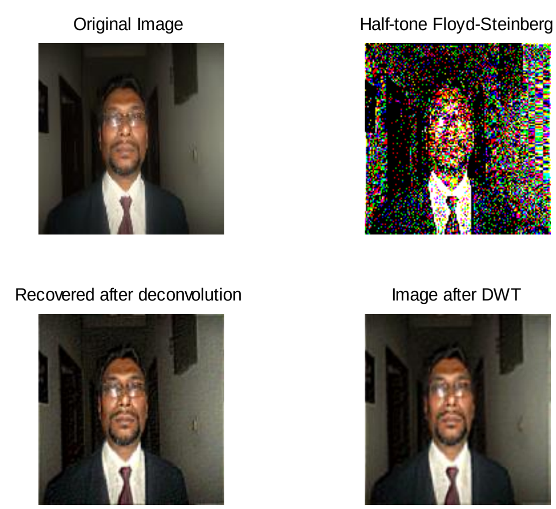

Figure 10. Gaussian Filter in Imdad Image

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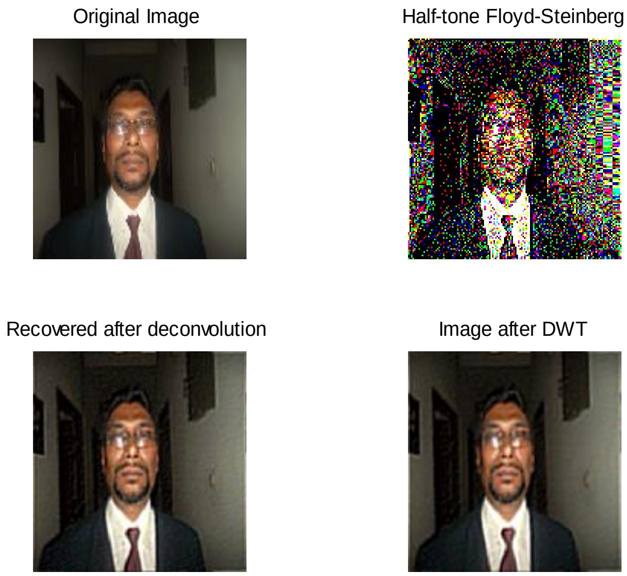

Figure 11. Disk Filter in Imdad Image

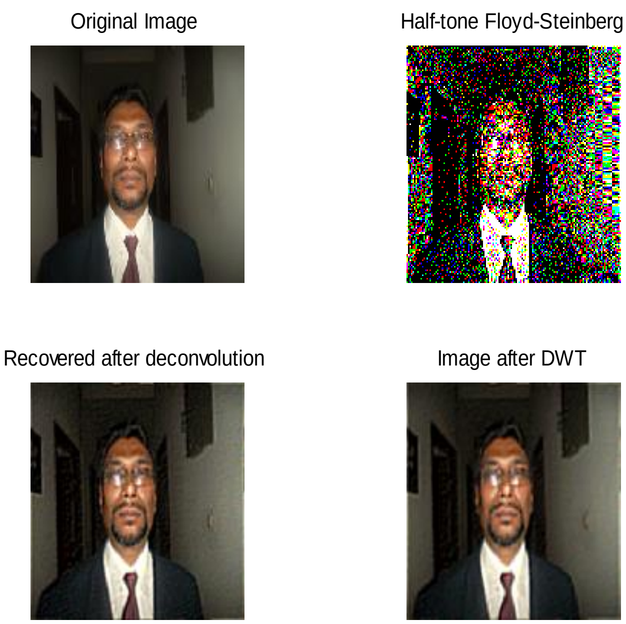

Figure 12. Average Filter in Imdad Image

In second stage, we compare the performance of four filters (used in convolution with half-tone image) of this paper, considering SNR in dB. In evaluating the SNR of recovered image, signal component is taken as the square sum of each pixel of the original image and noise is the mean square error between original recovered images. In this paper we made experiment on 100 images for comparison of four filters and only five are shown in Table V. From the Table V, the performance of the Gaussian, Disk and Average filters are very closed and better than Motion filter. Among the three, although performance is image dependent but Gaussian filter shows little better results. The relative performance of four filters are shown in Figure 5 to 12.

TABLE I. COMPARISON OF IMAGES OF FIGURE 1

		λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
Original Image	Red	1.0000	0.2577	-0.0354 +0.0443i	-0.0354 + 0.0443i	-0.0179 - 0.0434i	-0.0179 + 0.0434i
	Green	1.0000	0.1773	-0.1105	0.0205 + 0.0649i	0.0205 - 0.0649i	0.0169 + 0.0296i
	Blue	1.0000	-0.2095	0.1451	0.0186 - 0.1010i	0.0186 + 0.1010i	0.0592
Recovered Image	Red	1.0000	0.2579	-0.0346 +0.0445i	-0.0346 - 0.0445i	-0.0181 - 0.0431i	-0.0181 + 0.0431i
	Green	1.0000	0.1775	-0.1109	0.0211 + 0.0643i	0.0211 - 0.0643i	0.0164 - 0.0307i
	Blue	1.0000	-0.2103	0.1452	0.0188 - 0.1008i	0.0188 + 0.1008i	0.0590
Error	Red	0	-0.0002	-0.0008-0.0002i	-0.0008+0.0888i	0.0002-.0003i	0.0002+.0003i
	Green	0	-0.0002	0.0004	-0.0006+.0006i	-0.0006-.0006i	0.0005+.0603i
	Blue	0	0.0008	-0.0001	-0.0002-.0002i	-0.0002+.0002i	0.0002

TABLE II. **COMPARISON OF IMAGES OF FIGURE 2**

		λ_1	λ_2	λ_3	λ_4	λ_5	λ_6
Original Image	Red	1.0	-0.0748	0.0660	0.0429 - 0.0379i	0.0429 + 0.0379i	0.0382
	Green	1.0	-0.0820	0.0714	0.0355 - 0.0184i	0.0355 + 0.0184i	0.0386
	Blue	1.0	0.0735	-0.0716	0.0615 + 0.0000i	0.0355 + 0.0184i	0.0386
Recovered Image	Red	1.0	-0.0827	0.0802	0.0448 - 0.0331i	0.0448 + 0.0331i	0.0395
	Green	1.0	-0.0896	0.0863	0.0403 - 0.0167i	0.0403 + 0.0167i	0.0352
	Blue	1.0	0.0936	-0.0826	0.0567	0.0374 - 0.0059i	0.0374 + 0.006i
Error	Red	0	0.0079	-0.0142	-0.001900-.0048i	-0.001900+.0048i	-0.0013
	Green	0	0.0076	-0.01490	-0.004800-.0017i	-0.004800+.0017i	0.0034
	Blue	0	-0.02010	0.0110	0.004800	-0.001900+.0243i	0.0012-.006i

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TABLE III. **COMPARISON OF IMAGES OF FIGURE 3**

		λ_1	λ_2	λ_3
Original Image	Red	1.0	-0.0363 - 0.0509i	-0.036 + 0.051i
	Green	1.0	-0.0545 - 0.0539i	-0.0545 + 0.052i
	Blue	1.0	-0.0711 - 0.0591i	-0.0711 + 0.059i
Recovered Image	Red	1.0	-0.0408 - 0.0518i	-0.0408 + 0.052i
	Green	1.0	-0.0585 - 0.0518i	-0.0585 + 0.052i
	Blue	1.0	-0.0792 - 0.0554i	-0.0792 + 0.055i
Error	Red	0	0.0045+0.0009i	0.0045-0.0009i
	Green	0	0.004-.0021i	0.0040+.0021i
	Blue	0	0.0081-0.0037i	0.0081+.0037i

λ_4	λ_5	λ_6
0.0423 + 0.0000i	0.0239 + 0.0343i	0.0239 - 0.0343i
0.0449 + 0.0537i	0.0449 - 0.0537i	0.0261 + 0.0128i
0.0312 - 0.0544i	0.0312 + 0.0544i	0.0398 - 0.0038i
0.0261 - 0.0406i	0.0261 + 0.0406i	0.0461 + 0.0000i
0.0461 - 0.0620i	0.0461 + 0.0620i	-0.0346 + 0.0000i
0.0392 - 0.0621i	0.0392 + 0.0621i	-0.0499 + 0.0000i
0.0162+0.0406i	-0.0022-.00630i	-0.022200-0.0343i
-0.0012+0.1157i	-0.0012-0.1157i	0.060700+0.0128i
-0.0080+0.0077i	-0.0080-0.0077i	0.089700-0.0038i

TABLE IV. **COMPARISON OF IMAGES OF FIGURE 4**

		λ_1	λ_2	λ_3
Original Image	Red	1.0	0.0015 - 0.0668i	0.0015 + 0.0668i
	Green	1.00	0.2378	-0.0628 +0.0982i
	Blue	1.0	0.2086	-0.1509 +0.0964i
Recovered Image	Red	1.0	0.0129 - 0.0707i	0.0129 + 0.0707i
	Green	1.0	0.2240	-0.0558 +0.1132i
	Blue	1.0	0.2066	-0.1307 +0.1078i
Error	Red	0	-0.011400+.0039i	-0.0114-0.0039i
	Green	0	0.0138	-0.0070-0.0150i
	Blue	0	0.0020	-0.0202-0.0114i

λ_4	λ_5	λ_6
-0.0486 + 0.0332i	-0.0486 - 0.0332i	0.0011 + 0.0480i
-0.0628 - 0.0982i	0.0161 + 0.0488i	0.0161 - 0.0488i
-0.1509 - 0.0964i	-0.0373 - 0.1084i	-0.0373 + 0.1084i
-0.0585 + 0.0364i	-0.0585 - 0.0364i	-0.0020 - 0.0582i
-0.0558 - 0.1132i	0.0024 - 0.0634i	0.0024 + 0.0634i
-0.1307 - 0.1078i	-0.0425 - 0.1353i	-0.0425 + 0.1353i
.009900-.0032i	0.0099+0.0032i	0.0031+0.1062i
-.007000+.0150i	0.0137+0.1122i	0.0137-.1122i
-0.020200+0.0114i	0.0052+0.0269i	0.0052-0.0269i

TABLE V. COMPARISON OF SNR OF FILTERS

Components	SNR of Motion Filter in dB	SNR of Gaussian filter in dB	SNR of Disk filter in dB	SNR of Average filter in dB	Images
Red	7.7747	16.4960	15.7634	16.0332	JU Gate
Green	6.5125	15.3026	14.5977	14.8784	
Blue	6.3847	15.2154	14.5184	14.7953	
Red	6.2119	14.8887	13.9019	14.3437	Siam
Green	5.9047	14.7530	13.8176	14.2172	
Blue	5.0557	13.9224	13.0362	13.4149	
Red	7.5025	17.2172	16.3457	16.6884	Victory Monument
Green	6.9845	16.7158	15.7945	16.1585	
Blue	7.4790	16.7468	15.8596	16.2185	
Red	8.6051	18.0540	17.4465	17.7843	Memorial of 1952
Green	8.4645	18.1133	17.4971	17.8392	
Blue	8.6390	18.1281	17.5007	17.8464	
Red	5.2553	15.5891	15.3160	15.5506	Imdad
Green	4.4307	15.3795	15.1600	15.3910	
Blue	3.5105	14.9206	14.7957	14.9966	

TABLE VI. COMPARISON OF CROSS-CORRELATION COEFFICIENT OF ORIGINAL AND RECOVERED IMAGES UNDER DIFFERENT FILTERS

Components	Motion ρ	Gaussian ρ	Disk ρ	Average ρ	Image
R	0.8730	0.9428	0.9364	0.9399	JU Gate
G	0.9062	0.9596	0.9544	0.9571	
B	0.9352	0.9749	0.9713	0.9731	
R	0.8551	0.9371	0.9284	0.9332	Siam
G	0.8092	0.9081	0.8982	0.9040	
B	0.8172	0.9146	0.9055	0.9107	
R	0.9137	0.9663	0.9603	0.9631	Victory Monument
G	0.9309	0.9737	0.9687	0.9711	
B	0.9427	0.9784	0.9744	0.9763	
R	0.9483	0.9843	0.9802	0.9820	Memorial of 1952
G	0.9462	0.9839	0.9796	0.9815	
B	0.9484	0.9846	0.9805	0.9823	
R	0.9262	0.9773	0.9732	0.9751	Imdad
G	0.9168	0.9760	0.9719	0.9739	
B	0.9095	0.9755	0.9712	0.9733	

In Table VI, we compared the cross-correlation coefficient, ρ of Red, Green and Blue components of original and recovered image. We use the same images and filters of previous table and get the performance like before.

IV. CONCLUSIONS

In this paper, we recovered RGB image from its halftoned version using combination of image filtering and DWT. Here, we worked on halftone under Floyd-Steignberg algorithm. Still we have scope to work on other halftone algorithms for comparison. Our analysis will be helpful to save image storage and to save transmission time of image where lossy image compression is applicable. The compression ratio of our technique is much higher than JPEG since each pixel of colored halftone image requires only 3 bits instead of 24 bits of RGB image. Next we can introduce mask block such a way that zeros are filled at high frequency components. Now applying convolution on each block of the image with the mask can further reduce the size of image since we can apply run length code on the image with huge zeros.

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